Important arthropod pests on leafy Amaranth (*Amaranthus viridis*, *A. tricolor* and *A. blitum*) and broad-leafed African nightshade (*Solanum scabrum*) with a special focus on host-plant ranges

Mureithi DM[1,2,*], Fiaboe KKM[2], Ekesi S[2,] Meyhöfer R[1]
[1]Leibniz Universität Hannover, IGPS, Sect. Phytomedicine, Herrenhaeuser Str. 2 D-30419, Hannover- Germany
[2]International Centre of Insect Physiology and Ecology (ICIPE), P.O Box 30772-00100, Nairobi- Kenya
***Correspondence:** dmmureithi@gmail.com

Abstract

Leafy amaranths and African nightshades are important African Indigenous vegetables (AIVs) with numerous nutritional and health benefits. However, their production is faced with several challenges - key among them integrated control of arthropod pests. The insect groups attacking these vegetables include a range of hemipterans, dipterans, lepidopterans, and coleopteran species. Moreover, other crop and weed species frequently serve as alternative hosts to amaranth and nightshade pests in absence of the crops or when pest management measures have been applied. This review will evaluate the major pests attacking leaf amaranth and African nightshades and their potential host ranges. Potential viral diseases transmitted by these insects on African nightshades will also be highlighted. The ultimate aim of this review paper is to characterize infection pathways in the production system and agricultural landscape to develop new options of pest control.

Key words: African Indigenous vegetables, Infection pathways, Pest distribution.

Introduction

Among the main African indigenous vegetables (AIV) produced in Kenya are leafy amaranths and African nightshades (Mbugua et al., 2006; HCDA, 2012). Amaranthus tricolor, A. lividus, and A. blitum (Caryophyllales, Amaranthaceae) are grown for consumption of leaves (Amicarelli and Camaggio, 2012). The African nightshade species that are produced in Kenya include Solanum macrocarpon, S. scabrum and S. villosum (Solanales, Solanaceae). The insect groups attacking these two vegetables include; defoliators, sucking insects, stem borers, fruit/pod borers, leaf miners and webbers (Schippers, 2000; Sithanantham et al., 2003). Development of sustainable integrated pest and disease management strategies are of high priority in the production of healthy vegetables. In this context, world distribution of amaranth and nightshade pests in general and in East Africa in particular, host ranges and their damage are discussed with the aim of characterizing their infection/infestation pathways in the production system and agricultural landscape.

Pests of amaranth and their host ranges

Amaranth is attacked by numerous herbivorous arthropod pests that feed on various plant parts such as roots, stems, leaves, flowers and seeds. The major insect groups causing considerable losses to amaranth belong to the orders Lepidoptera, Coleoptera, Hemiptera, and Diptera (Clarke-Harris *et al.*, 1998).

Beet webworm, *Spoladea recurvalis* Fabricius (Lepidoptera; Crambidae) is distributed in tropical and sub-tropical regions of Asia, Africa and Australia. Other than amaranth, Garden beet and swiss chards are other Chenopodeaceae crops commonly grown in amaranth production zones in East Africa and might serve as major hosts of *S. recurvalis*. The pest also attacks several weed species that are found in amaranth fields including *Chenopodium album* (Chenopodiaceae), *Portulaca oleracea* (Portulacaceae), and *Trianthema portulacastrum* (Aizoaceae) (Table 1)

(Capinera, 2011; Kedar *et al.*, 2013). Alternative hosts could serve to perpetuate the pest in absence of amaranth or further increase their population if present together with amaranth due to abundance in food sources. The larvae skeletonize the leaves before rolling them to provide shelter during pupation. Huge losses caused by *S. recurvalis* on amaranth have been reported in Nigeria (Aderolu *et al.*, 2013).

Cotton leafworm *Spodoptera littoralis* Boisduval (Lepidoptera; Noctuidae) is a severe lepidopteran pest of amaranth and African nightshade. The pest is widely distributed throughout Africa including East African countries of Kenya, Uganda and Tanzania. It is also present in other tropical and sub-tropical regions of Asia and Europe (Miller, 1976; Sidibe and Lauge, 1977). *Spodoptera littoralis* is a highly polyphagous species which is able to feed on more than 87 plant species covering 40 different families such as Amaranthaceae, Brassicaceae, Liliaceae, Malvaceae, Chenopodiaceae, Fabaceae, Solanaceae, Curcubitaceae, and Poaceae. Besides amaranth, onion, cabbage, capsicum, beans, maize, potato, tomato and eggplants are potential major hosts of the pest grown in amaranth production areas. Minor hosts in the familyApiaceae such as carrots are also grown in amaranth production areas and could serve as an alternative host to *S. littoralis*. Wild hosts such as lantana (Verbenaceae), jatropha (Euphorbiaceae) and wild strawberries (Rosaceae) could also provide food resources (nectar and foliage) to the pest (Table 1) (Salama *et al.*, 1970; Brown and Dewhurst, 1975; Badr, 1982; Rizk *et al.*, 1988; Holloway, 1989; Mohamed, 2003 The ability of the pest to fly long distances could enable *S. littoralis* to reach many other hosts which may be far away in absence of amaranth crop and later return to infest newly established amaranth. The pest is a voracious feeder shredding leaves of the host plant and leaving large irregular holes. Considerable yield losses on amaranth have been reported in Nigeria and Mexico (Aragón *et al.*, 1997; Aderolu *et al.*, 2013).

Amaranth stem weevils, *Hypolixus* sp. (Coleoptera; Curculionidae) are among the most serious coleopteran pests of amaranth. Species known to be destructive to the crop include *H. truncatulus*, *H. haerens*, and *H. nubilosus* (Gupta and Rawat, 1954; Louw *et al.*, 1995; Torres-Saldaña *et al.*, 2004; Kagali *et al.*, 2013). Besides Amaranth, no other host plant has been documented for *Hypolixus* sp suggesting that the pest could be managed by cultural practices such as closed season or crop rotation (Table 1). Weevil larvae damage the stem by burrowing and feeding on the stem tissues and leaving their excreta therein while the adults are leaf-feeders. Feeding by the pest causes stunting, reduction in leaf yield, development of tumors on the stem and eventual drying up of the plant (Tara *et al.*, 2009; Imam *et al.*, 2010). Plant infestation of up to 81 % has been reported in India.

The pea leafminer, *Liriomyza huidobrensis* Blanchard (Diptera; Agromyzidae) is among the leafminer flies challenging the production of amaranth. *L. huidobrensis* is widespread in the Mediterranean region. However, it has colonized other regions of the world (America, Asia, Africa and the Oceania). In East Africa, it has been reported in Kenya and Tanzania (Chabi-Olaye *et al.*, 2008; EPPO 2014; Foba *et al.*, 2015). *Liriomyza huidobrensis* is highly polyphagous and is known to attack host plants from 14 different families, both cultivated and wild including amaranth. Other popular crops grown alongside amaranth which the pest uses as host include faba beans, onions, garlic and snowpeas. Oxalis, datura and tagetes are wild hosts of *L. huidobrensis* that invade amaranth farms leading to higher epidemics of the pest (Table 1) (Mujica and Kroschel, 2011; Foba *et al.*, 2015). The pest manifests itself by burrowing irregular white mines with dampened black and dried brown areas on the leaves. Yield losses of between 20-100% on different crops have been reported in Kenya (Spencer 1973, 1990; OEPP/EPPO, 2005).

Table. 1 Pests of Amaranth and host range on crops and weeds (--- = no information available)

Order	Family	Species	Distribution	Major hosts	Other hosts	Weed hosts	Damage	Importance	Reference
Coleoptera	Curculionidae	*Hypolixus sp* Amaranth stem weevil	India, Mexico, Nigeria, South **Africa**, **Kenya**	*Amaranthus* sp	---	---	Stem burrowing by larva Adults feed on leaves	A serious pest of amaranth in Mexico, India, South Africa and Kenya	Gupta and Rawat 1954; Louw *et al.*, 1995; Torres-Saldaña *et al.*, 2004; Kagali *et al.*, 2013; Tara *et al.*, 2009; Imam *et al.*, 2010
Diptera	Agromyzidae	*Liriomyza huidobrensis* Sepentine leaf miner/ Pea leaf miner	Mediterranean region, present in several countries in America, Asia, Oceania, **Africa** including **Kenya**	*Amaranth* sp, *Gypsophila* sp, *Vicia faba*, *Allium cepa*, *Allium sativum*, *Dianthus caryophyllus*, *Cucumis sativus*, *Lactuca sativa*, *Solanum tuberosum*, *Spinacia oleracea*, *Pisum sativum*, *Raphanus sativus*	---	*Oxalis sp*, *Datura stramonium*, *Sonchus* sp., *Tagetes* sp.	Irregular white mines with dampened black and dried brown areas on the leaves.	Lowering of aesthetic value of ornamentals,yield reduction in vegetables	CABI/EPPO 2002; EPPO 2014; Spencer 1973 1990; OEPP/EPPO 2005; Mujica and Kroschel 2011
Diptera	Agromyzidae	*Liriomyza sativae* Vegetable leaf miner	Worldwide, in **Africa**, reported from **Kenya**, Sudan, Nigeria, Cameroon, and Zimbabwe	*Medicago sativa*, *Solanum melongena*, *Capsicum* sp, *Solanum lycopersicum*, *Solanum tuberosum*, *Pisum sativum*	*Amaranthus* sp., *Aster* sp., *Cucumis sativus*, *Apium graveolens*, *Lathyrus* sp, *Citrullus lanatus*, *Tropaeolum* sp	*Erechtites hieraciifolia*, *Synedrella nodiflora*, *Deeringia amarantoides*, *Ipomoea aquatic*, *Basella alba*	Mines on the leaves	Losses of up to 80 % have been recorded in celery and *Medicago sativa*, severe yield loss in tomato and other field crops Transmission of Celery mosaic potyvirus	Smith *et al.*, 1962; Musgrave et al., 1975; Zitter *et al.*, 1980; Spencer, 1982; CIE 1986
Hemiptera	Aphididae	*Myzus persicae* Green peach aphid	Worldwide except in areas with extreme temperatures and moisture	*Apium graveolens*, *Arachis hypogaea*, *Capsicum* sp, *Carika papaya*, *Citrullus lanatus*, *Daucus*	*Pisum sativum*, *Vigna unguiculata*, *Solanum nigrum*	Dicotyledonous weeds	Direct damage through sucking of plant sap	Heavy losses have been reported on potato,	Millar 1994; CIE 1979; Remaudiere & Autrique 1985; Heathcote 1962;

Order	Family	Species	Distribution	Major hosts	Other hosts	Weed hosts	Damage	Importance	Reference
				carota, *Nicotiana tabacum*, *Phaseolus vulgaris*, *Zea mays*, *Solanum esculentum*, *Solanum tuberosum*, *Solanum melongena*			Transmission of plant viruses	sugarbeets, and peach	Tamaki 1975; Barbagallo *et al.*, 2007
Hemiptera	Cicadellidae	*Empoasca sp* Leafhopper	Nigeria	*Amaranthus* sp, *Nicotiana tabacum*	---	---	Sucking plant sap from the leaves causing "hopper burn"	Vectoring viruses, bacteria, and fungi	Aragón *et al.*,, 1997; Kallenbach *et al.*, 2012
Hemiptera	Miridae	Lygus lineolaris Tarnished plant bug	Canada, Mexico, USA, Nigeria	*Amaranthus* sp, *Daucus carota*, *Gossypium hirsutum*, *Phaseolus lunatus*, *Medicago sativum*, *Phaseolus vulgaris*, *Glycine max*, *Solanum esculentum*, *Malus domestica*, *Prunus avium*, *Prunus persica* , *Pyrus communis*, *Fragaria Ananassa*	Most vegetable crops	---	Yellowing and distortion of terminal growth, ragged and discoloured leaves Flower abortion	Losses of up to 50 % have been reported on nursery stock	Haseman 1918; Tingey and Pillemer 1977; Young 1986; Aragón *et al.*, 1997; Capinera 2001
Lepidoptera	Crambidae	*Herpetogramma bipunctalis* Southern beet webworm moth	Many tropical and **sub-tropical regions** of the world	*Beta vulgaris subsp. vulgaris, spinacia oleracea*, *Amaranthus* sp	*Capsicum* sp, *Zea mays*, *Gossypium hirsutum*, *Brassica* sp, *Medicago sativum*, *Arachis hypogaea*, *Solanum tuberosum*,	Purslane, *Portulaca oleracea Solanum nigram*, *Chenopodium album*, *S. indicum*	Larva burrows and feed on the stem tissues causing lodging and death of the plants.	---	Allyson 1984; Solis 2006; Capinera 2011; www.africanmoths.com

Order	Family	Species	Distribution	Major hosts	Other hosts	Weed hosts	Damage	Importance	Reference
					Solanum esculentum				
Lepidoptera	Crambidae	*Spoladea recurvalis*, Hawaiian beet webworm	**Many African countries**	*Beta vulgaris*, *Amaranthus* sp	---	*Chenopodium album*, *Portulaca oleracea*, *Trianthema portulacastrum*	Sclerotization and rolling of the leaves	Most abundant pest of amaranth in Nigeria	Capinera 2011; Aderolu *et al.*, 2013; Kedar *et al.*, 2013
Lepidoptera	Noctuidae	*Spodoptera littoralis* Cotton leafworm	Subtropical and tropical range, **Africa**, Asia, Turkey, Spain, Greece	*Amaranthus* sp, *Allium cepa*, *Brassica* sp, *Capsicum* sp, Curcubitaceae, *Gossypium hirsutum*, *Phaseolus vulgaris*, *Zea mays*, *Spinacea oleracea*, *Solanum tuberosum*, *Solanum esculentum*, *Solanum melongena*	Apium graveolens, *Trigonella Foenum*, *Musa domestica*, *Asparagus officinalis*	*Lantana camara*, *Jatropha curcas* , *Hibiscus rosa-sinensis*	Shredding of leaves Premature fruit drop Holes on fruits	Considerable leaf yield losses on amaranth Severe damage to flowering and fruiting points on cotton and cowpea	Miller 1976; Sidibe and Lauge 1977; Salama *et al.*, 1970; Brown and Dewhurst 1975; Badr 1982; Rizk *et al.*, 1988; Holloway 1989; Mohamed 2003; Aragón *et al.* 1997 Aderolu *et al.*, 2013
Lepidoptera	Pyralidae	*Sylepta derogota* Cotton leaf roller	**Africa,** Asia, Oceanic	*Abelmoschus esculentus*, *Gossypium hirsutum*, *Manihot esculenta*, *Corchorus* olitorius	*Solanum esculentum*, *Solanum melongena*, *Amaranthus sp*, *Durio zibethinus*, *Coleus* sp.	---	Feeding on leaf margins Leaf rolling	Losses of between 10-14 % have been reported on cotton	Odebiyi 1982; Zang 1994; CABI 2007; The Natural History Museum 2007

The green peach aphid, *Myzus persicae* Sulzer (Hemiptera; Aphididae) is distributed throughout the world except in areas with extreme temperatures or moisture. The pest is present in East African countries including Kenya (Millar, 1994; CIE, 1979; Remaudiere & Autrique, 1985). *M. persicae* is a serious pest of Amaranth. Groundnuts, capsicums, carrots, maize, beans, potato, tomato and eggplants which are cultivated in amaranth growing regions of East Africa also serve as alternative hosts of *M. persicae* leading to high population build-up of the pest (Table 1) (Heathcote, 1962; Tamaki 1975). Significant yield losses have been reported in potato, sugarbeets and peach (Barbagallo *et al.*, 2007). The pest vectors important plant viruses such as Potato leaf roll virus (PLRV), Potato virus Y (PVY), Cucumber mosaic virus (CMV), and Pepper veinal mottle virus (PVMV). Among the listed viruses, PVY is the only one that has been shown to infect amaranth experimentally. However, the other virus could also infect amaranth as they are hosted by other plant species that also grow in the same neighbourhood as amaranth such as potato, tomato, capsicums, and pumpkin. Common weeds in amaranth fields such as datura and *Physalis ungulata* are also hosts of the viruses listed., (http://www.cabi.org; Kennedy *et al.*, 1962).

Other important pests infesting leaf amaranth that have been reported in Africa include; *Sylepta derogota* (Lepidoptera; Pyralidae), *Herpetogramma bipunctalis* (Lepidoptera, Crambidae), *Liriomyza sativae* (Diptera; Agromyzidae), and *Empoasca* sp. (Hemiptera; Cicadellidae) (Table 1) (Aragón *et al.*,1997; Garcia *et al.*, 2011; Sæthre *et al.* 2011; Aderolu *et al.*, 2013; Kagali *et.al*., 2013). Although scanty information is available on some of these pests with regard to their geographical distribution in Africa, host range, virus transmission and economic importance, they pose a serious challenge in production of Amaranth due to their long distance flight capability particularly the Lepidopterans and the Dipterans.

Pests of African nightshades and their host ranges

African nightshade is attacked mainly by herbivorous arthropod pests that feed on leaves. More than 13 insect species belonging to orders Hemiptera, Lepidoptera, and Diptera as well as spider mites have been reported to attack African nightshades. The most serious pests on African nightshades are discussed.

Aphids (Hemiptera; Aphididae) are among the most important sucking insects attacking African nightshades. The leaves infested by aphids curl and fold causing distorted and retarded growth of young apical shoots. Moreover, aphid infestation significantly reduces crop quality through contamination with honeydew and subsequent sooty mould, leading to frequent markets rejections. (AVRDC, 2003; Varela and Seif, 2004). The major aphid species attacking African nightshades include *Aphis gossypii, A. craccivora,* and *A. fabae* (Ashilenje *et al.*, 2011; Suganthy and Sakthivel, 2012; Singh *et al.*, 2014).

The cotton aphid, *A. gossypii* Glover is present worldwide including the East African region. It can survive in both hot and cold regions of the world (UK CAB International, 1968). The pest has a wide host range in over 92 plant families. Among the primary hosts are crops in the Malvaceae, Cucurbitaceae, and Solanaceae families such as cotton, pumpkins, cucumber tomato, and nightshades. Other hosts of the pest include; maize, beans, cabbages, kales, and *Bidens pilosa* (Table 1) (Ebert and Cartwright., 1997). Presence of the mentioned host plants in East Africaenables the perpetual survival of *A. gossypii* in farmlands throughout the year and recolonisation of the new nightshade crop upon establishment. Transmission of viruses is the most devastating impact of the pest with a potential of transmitting over 30 plant viruses such as Cucumber mosaic virus (CMV), Pepper veinal mottle virus (PVMV) and Potato leafroll virus (PLRV) (http://www.cabi.org; Kennedy *et al.*, 1962; Ebert and Cartwright, 1997). These viruses are present in East Africa and have been

reported to infect nightshades alongside other Solanaceae crops such as tomato, potato, capsicums, and weed species such as datura and *Physalis ungulata*. Melon, Pumpkin, common beans, faba beans, maize and Oxalis are also hosts of CMV and could serve as a reservoir of the virus in absence of nightshades. Yield losses of up to 80% have been reported on cotton in Zambia. However, losses on African nightshades are yet to be quantified.

The cowpea aphid, *A. craccivora* Koch, has a wide distribution in the tropics where it is among the most common aphid species. Among other East African countries, the pest is also present in Kenya (CIE, 1983; Blackman and Eastop, 2000). Although *A. craccivora* has higher preference for plants in the Fabaceae family, it is a polyphagous pest that uses 18 other plant families such as Amaranthaceae, Solanaceae, and Malvaceae. Host crops for *A. craccivora* that are found areas where nightshades are grown in East Africa include; beans, cowpea, mung beans, pigeon peas, groundnuts, pepper, amaranth and citrus fruits. Wild hosts to the pest include; *Commelina benghalensis*, *Palisota hirsute*, *Boerhavia diffusa*, and *Portulaca oleracea* (Table 2; Sæthre *et al.*, 2011). *A. craccivora* transmits about 30 different plant viruses including Cucumber mosaic virus (CMV), and Alfalfa mosaic virus (AMV) that are known to infect nightshades and other common vegetables present in nightshade growing areas of East Africa such as tomato, potato, pepper, common beans, faba beans, eggplant, and beetroot. (http://www.cabi.org; Jones, 1967; Bock 1973).

The black bean aphid, *A. fabae* Scopoli, is highly polyphagous and plants in the families Solanaceae, Amaranthaceae, Chenopodiaceae, Brassicaceae, Cucurbitaceae, and Fabaceae serve as suitable hosts. Among the potential alternative cultivated hosts of *A. fabae* in nightshade production areas are; common beans, runner beans, and broad beans. Common weeds found in nightshade farms that could serve as alternative hosts to *A. fabae* are *Chenopodium album, Physalis wrightii, Sonchus oleraceus Amaranthus retroflexus*, and *Amysynchia intermedia* (Table 2). The major damage by this pest is through direct feeding (Cammell and Way, 1983). Although *A. fabae* transmits over 30 viruses, the damage is low on other plants except *Beta vulgaris*. Important virus transmitted by *A. fabae* and is present in East Africa is Potato virus Y (PVY). The virus not only infect nightshades but other crops and weed species discussed earlier in this review that are present in nightshade growing areas.

Spidermites, *Tetranychus* spp. (Trombidiformes; Tetranychidae), are a menace in production of African nightshades particularly in dry weather conditions. The underside of African nightshade leaves attacked by spidermites turn bronze, rusty or yellowish. Severe infestation results to cobwebbing on the plant and may lead to the death of the plant. *Tetranychus evansi* Baker & Pritchard and *Tetranychus urticae* Koch cause most serious damage to African nightshades (Jepson *et al.*, 1975; Moraes *et al.*, 1987; Park and Lee 2002; Fiaboe *et al.*, 2006; Murungi *et al.*, 2011).

Tomato red spider mite, *T. evansi* originated from South America. However, it is currently distributedin many African countries including Kenya (Migeon & Dorkeld, 2006-2012). *T. evansi* is a specialist spidermite species mainly foraging on plants in the Solanaceae family. Tomato, potato and eggplant commonly grown in the same agroecological zone or in the same field with African nightshades are the other preferred Solanaceae hosts (Moraes *et al.*, 1987). Minor hosts are in Asteraceae, Fabaceae, Cucurbitaceae, Malvaceae, Poaceae, Chenopodiaceae, Euphorbiaceae, Amaranthaceae and Brassicaceae families among others (Migeon and Dorkeld 2006–2012). *Chenopodium* sp., *Conyza* sp., and *Sonchus* sp. are common weeds in nightshade fields that also serve as alternative refuge to *T. Evansi* (Table 2). Losses of 90% have been

reported in field trials in Namibia (Jeppson *et al.*, 1975; Gutierrez & Etienne, 1986).

The two spotted spider mite, *Tetranychus urticae* is widely spread in many parts of the world. It was reported in Kenya in 1996 (IIE, 1996; Bolland *et al.*, 1998). *T. urticae* has a wide host range from wild plants, ornamentals, vegetable plants, and fruits. Other than African nightshades, it forages on many other crops such as tomato, common beans, cucumber, eggplant, pepper, sorghum onion, garlic and cotton, many of which are grown in similar areas as nightshades thereby serving to perpetuate the pest further (Table 2; Jepson *et al.*, 1975; Bolland *et al.*, (1998). Economic damage of 13 % has been recorded on Soybean.

Flea beetles (*Phyllotreta* sp. and *Epitrix* sp.), *Herpetogramma bipunctalis*, *Agrotis* sp., Sp*odoptera* sp., *Tuta absoluta*, whiteflies, thrips, *Liriomyza* sp. and nematodes (*Meloidogyne* sp.) are other important pests of African nightshades and many other crops and weed species in nightshade growing zones. Flea beetles have particularly been observed to cause immense damage in African nightshades farms in Kenya although they have not been properly documented.

Conclusion

Although the major pests of leafy amaranth are chewing insects mainly Lepidopterans and Coleopterans, production of African nightshades is chiefly constrained by sucking insects particularly the aphids and spider mites. The importance of the mentioned key pests is due their abundance in amaranth and nightshade farms, and the direct and indirect damage they cause on the crop. This has been supported by own survey done in Kenya (unpublished data). The plant host range for many pests of the two crops are broad, cutting across many vegetable, agricultural crops as well as and weed species commonly found in or around amaranth or nightshade growing fields. However, some of the pests are specialist herbivores mainly feeding on Amaranthaceae or Solanaceae families. Sucking pests know to transmit plant viruses are more important in Nightshades, therefore it is likely that viral diseases play a larger role in constraining production of African nightshades compared to Amaranth. There are also a higher number of other hosts and weed species for pests of African nightshades as compared to Amaranth possibly due to a lower number of sucking insects infesting amaranth or due to missing information on host range of some of the pests of Amaranth. In considering integrated pest management measures for both crops, whole farm evaluation should be done taking in to account not only the crop of interest but also the other crops and weed species present in the farm. Larger areas should be considered for management of amaranth pests due to their ability to fly longer distances particularly the Lepidopterans.

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Table. 2 Pests of African nightshades and host range on crops and weeds.

Order	Family	Scientific Name Common Name	Distribution	Major hosts	Other hosts	Weed hosts	Damage	Importance	References
Coleoptera	Chrysomelidae	*Epitrix* sp Potato flea beetle	North, Central and South America, Portugal, **Kenya** (during recent surveys)	*Solanum tuberosum*, *Solanum scabrum*, *Solanum melongena*, *Nicotiana tabacum*, *Capsicum sp*, *Solanum esculentum*	Chenopodiaceae, Cucurbitaceae, Fabaceae, Brassicaceae, Poacea,	*Datura stramonium*, *Solanum nigrum*, *S. trifolium*	Shot-holes on the leaves	Yield losses up to 20 % have been reported	Neilson & Finlayson 1953; Wallis 1957; CABI 2007; Boavida & Germain 2009
Coleoptera	Chrysomelidae	*Phyllotreta* sp Striped flea beetle	No information, but observed in **Kenya** during 2014 survey	Brassicaceae	*Amaranthus* sp *Beta vulgaris*	Weed plants in the families Euphorbiaceae, Asteraceae, Solanaceae	Shot-holes on the leaves	Leaf damage of up to 71 % has been observed on *Brassica oleraceae* var. *capitata*	Mayori & Mikunthan 2009
Hemiptera	Aleyrodidae	*Bemisia tabaci* Sweet potato whitefly	**Africa**, Asia, North America, South America, Oceania	Many plant families	Many plant families	Many	Leaf chlorosis Viruses transmission	Yield losses to crops of between 20 and 100 % have been reported from Geminiviruses	Mound & Halsey 1978; IAPSC 1985; CIE 1986; Brown & Bird 1992; Perring *et al.,* 1993
Hemiptera	Aleyrodidae	*Trialeurodes vaporariorum* Greenhouse whitefly	Widespread in many parts of the world including **Africa**	Many vegetable and agricultural crops	Many vegetable crops	*Stellaria media*	Necrotic spots on leaves, tissue distortion, dwarfing	Direct feeding, virus transmission (Beet pseudo-yellows virus, Strawberry pallidosis virus)	Byrne *et al.,* 1990; EPPO 2014
Hemiptera	Aphididae	*Aphis craccivora* Cowpea Aphid/ Groundnut Aphid	Abundant in subtropical and tropical regions and the Mediterranean	*Phaseolus vulgaris*, *Vigna unguiculata*, *Vigna radiata*, *Arachis hypogaea*, *Cajanus cajan*	*Solanum scabrum*, *Lactuca sativa*, *Gossypium hirsutum*, *Capsicum* sp, *Citrus* sp, *Amaranthus* sp	*Commelina benghalensis*, *Palisota hirsute*, *Boerhavia diffusa*, *Portulaca oleracea*	Direct feeding, virus transmission.	Transmits about 30 plant viruses on Groundnuts, Beans, Peas, Brassicaceae, Cucurbits, and Beets.	Jones 1967; Bock 1973; CIE 1983; Blackman & Eastop 2000
Hemiptera	Aphididae	*Aphis fabae* Black bean aphid	Worldwide	*Beta vulgaris*, *Phaseolus vulgaris*, *Phaseolus coccineus*, *Vicia faba*	Many vegetable and agricultural crops	*Chenopodium album, Physalis wrightii, Sonchus oleraceus Amaranthus*	stunting of the plants or death in severe infestation.	Yield and quality reduction particularly on crops in Fabaceae family, serious injury due to	Cammell and Way 1983; Fernandez-Quintanilla *et al.*,2002

Order	Family	Scientific Name Common Name	Distribution	Major hosts	Other hosts	Weed hosts	Damage	Importance	References
						retroflexus, *Amysynchia intermedia*		transmission of viruses has only been witnessed on *Beta vulgaris*	
Hemiptera	Aphididae	*Aphis gossypii* Cotton Aphid/ Melon aphid	Widespread worldwide	*Carica papaya*, *Cucurbita pepo*, *Cucumis sativus*, *Gossypium hirsutum.* *Solanum esculentum*	Many crops in the families; Brassicaceae, Fabaceae, Solanaceae, Poaceae	*Bidens pilosa*, *Commelina benghalensis*, *Brachiaria lata*	Yellowing and curling of leaves, sooty moulds on leaves	Over 30 plant viruses transmitted including Potato leafroll virus, Pepper veinal mottle and virus	Kennedy *et al.*, 1962; UK CAB International 1968; Ebert & Cartwright 1997
Lepidoptera	Gelechiidae	*Tuta absoluta* Tomato leafminer	South America, Israel**, Several African countries including; Kenya, Tanzania, Ethiopia**, Senegal, Nigeria, Niger, Egypt, Algeria	*Solanum esculentum*	*Solanum scabrum* *Solanum tuberosum*	*Solanum elaeagnifolium*, *Solanum puberulum*, *Datura stramonium*, *Datura ferox*, *Nicotiana glauca*	Burrows into the leaves lowering the photosynthetic rate of the plants	100 % economic loss has been reported on tomato Ban on trade on commodities infested by the pest	Garcia & Espul 1982; Zappalà *et al.*, 2012; Zlof & Suffert 2012; CABI/EPPO 2013; IPPC 2014
Lepidoptera	Noctuidae	*Agrotis* sp. Cutworm	Widely distributed in **Africa**	Allium cepa, *Abelmoschus esculentus*, *Arachis hypogaea*, Brassicaceae, *Cicer arietinum*, *Solanum esculentum*, *Solanum tuberosum*, *Zea mays*	*Agrostis palustris*, *Poa pratensis* *Prunus persica*, *Prunus domestica*	*Mentha* sp, *Solanum nigrum*, *Convolvulus* sp	Cutting the seedling stems at the ground level	May cause economic injury to seedlings of maize, many vegetables, cotton, tobacco, turf grasses	CIE 1969
Nematoda	Tylenchormoph a	*Meloidogyne javanica* *Meloidogyne enterelobii* *Meloidogyne incognita*	Tropical and sub-tropical regions of the world including Kenya	*Solanum scabrum*, *Solanum villosum*, *Solanum esculentum*	Many agricultural crops such as. *Curcubita pepo*, *Citrullus lanatus*, *Amaranthus* sp, *Coffea* sp	*Bidens pilosa*, *Ageratum conyzoides*, *Emex australis*, *Galinsoga parviflora*	Development of root-knots Yellowing accompanied by stunted growth	10-100 yield loss	CABI/EPPO, 2002a; CABI/EPPO, 2002b; Chitambo et al., 2016

Order	**Family**	**Scientific Name Common Name**	**Distribution**	**Major hosts**	**Other hosts**	**Weed hosts**	**Damage**	**Importance**	**References**
Trombidiformes	Tetranychidae	*Tetranychus evansi* Tomato red spider mite	Many **African** countries, South America	*Solanum esculentum*, *Solanum melongena*, *Nicotiana tabacum*, *Solanum tuberosum*	Plants in the following families; Asteraceae, Fabaceae, Cucurbitaceae, Malvaceae, Poaceae, Chenopodiaceae, Euphorbiaceae, Amaranthaceae Brassicaceae	*Chenopodium* sp., *Convolvus* sp., *Conyza* sp., *Diplotaxis* sp., *Hordeum murinum*, *Lavatera* sp., *Sonchus* sp.	Leaves turn bleached yellow-orange followed by rapid death	Most important dry season pest of tomato in South Africa and in Réunion; losses of 90 % have been reported in field trials in Namibia	Jepson *et al.*, 1975; Gutierrez & Etienne 1986; Moraes *et al.*,,1987; Migeon & Dorkeld 2006-2012
Trombidiformes	Tetranychidae	*Tetranychus urticae* Red spider mite/ two spotted red spider mite	Widely distributed in the world including **Africa**	Solanum esculentum, Phaseolus vulgaris, *Gossypium hirsutum*, *Zea mays*, *Cucumis sativus*, *Sorghum bicolor*, *Solanum melongena*, *Capsicum* sp	*Allium cepa*, *Allium sativum*	Many weeds in the families; Solanaceae, Fabaceae, Malvaceae, Poaceae, Cucurbitaceae, Liliaceae, Chenopodiaceae	Reduction to the photosynthetic rate of leaves	Yield reduction on cotton, tomato, apple, peach and strawberry. Fruit damage leading to reduction in fruit quality on tomato	Jepson *et al.*, 1975; Sances *et al.*, 1982; Mobley & Marini 1990; Nihoul *et al.*, 1992; Bondada *et al.*, 1995; IIE 1996; Bolland *et al.*, 1998; Meck *et al.*, 2012

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